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THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

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SELENIUM POISONING IN HORSES IN NORTH QUEENSLAND

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SUMMARY.

A disease of horses in Cape York Peninsula known locally as "change hoof disease" is described.

The gross pathology in field cases, involving laminitis, loss of hair from the mane and tail and hoof sloughing, parallels that reported in chronic selenium poisoning elsewhere.

Levels of selenium found in organs and tissues from field cases are comparable with those found in selenised horses in the U.S.A. and Ireland. Selenium contents of 2.6, 12.0, 6.0 and 6.8 p.p.m. respectively were found in the liver, mane, tail and hoof of one horse, and the mane and tail of another contained 2.5 and 1 p.p.m. selenium respectively.

The selenium content of the incriminated plant, Morinda reticulata, **varied from 1.5 to 1,141 p.p.m. on a dry-matter basis but was generally well in excess of the minimum required to cause chronic selenosis.**

The feeding of 138 lb. of M. reticulata, **containing 13.3 g. Se, to a horse over an 82-day period caused lameness and loss of hair. Analyses of samples taken at autopsy showed 9.8 p.p.m. Se in the liver and the following levels in hair grown during the trial—body hair 11.2, mane 19.4 and tail 45.4 p.p.m.**

I. INTRODUCTION.

Selenium, discovered by Berzelius in 1817, was shown to be toxic to animals in 1842 (Japha 1842). Cameron (1880) demonstrated the ability of plants to absorb this element.

A disease of dragoon horses at Fort Randall, Nebraska, in 1856, characterised by lameness and loss of hair from the mane and tail (Madison 1860), was the first report of the disease later known as "alkali disease". Subsequently this disease was shown to occur over large areas of semi-arid plains of North America and to affect all grazing stock. A similar disorder resulted in animals fed grains grown in these areas. A much more rapidly fatal disease, "blind staggers", caused stock losses, particularly in Wyoming.

The connection between these apparently unrelated enzootic diseases and selenium was not suspected till Franke (1934) postulated a rare toxic element in grain from affected areas. The presence of selenium in this grain was demonstrated by Robinson (1933). Independent investigation in Wyoming showed that "blind staggers" was also due to the ingestion of herbage containing selenium (Beath, Eppson and Gilbert 1935).

Since then selenosis has been reported from many areas of the United States (Russel and Duncan 1956); from Saskatchewan, where the disorder "frozen feet" occurs in conditions of extreme cold (Williams, Lakin and Byers 1941); from Mexico, where the local name is "soliman disease" (Williams, Lakin and Byers 1940); and from Colombia (Ancizar-Sordo 1947).

The first reported case of selenosis outside the Americas was an isolated occurrence in County Limerick in Ireland (Walsh, Fleming, O'Connor and Sweaney 1951). Later, selenosis was demonstrated in Counties Tipperary and Meath (Fleming and Walsh 1957).

In Queensland a condition in horses involving laminitis and loss of mane and tail hair had been known locally in northern Cape York Peninsula since the area was first settled in 1864. This condition, called "change hoof disease", was brought to our attention when the Department of Native Affairs attempted to establish cattle at the Bamaga Settlement in the Cape York area. In March 1954 the Superintendent of Bamaga reported: "A horse muster has been completed on known settlement horses. Total mustered 9 including 3 draught horses. Two more are in the bush too lame to come in. All these with the exception of one draught are in various stages of changing their hoofs and are very lame. They will not be fit for work for several months".

In December 1955, Bamaga Settlement was visited at the request of the Department of Native Affairs. As a result of observations in the area and discussion with local residents the plant *Morinda reticulata* was suspected of causing the disease.

Records of the Queensland Herbarium show that a plant specimen identified as *M. reticulata* had been submitted from the Temple Bay area in 1923 and was reputed to cause founder and hoof abnormalities in horses.

In January 1956, McGavin (unpublished Departmental report) reported "change hoof disease" at the Arukun Mission at the mouth of Archer River. Again it was observed that the disorder occurred in an area carrying *M. reticulata*.

The results of the 1955 field investigations and subsequent feeding trials and laboratory findings are presented here.

II. FIELD INVESTIGATIONS.

Bamaga Settlement lies in a zone of 70 in. annual rainfall which is characterised by a predominantly December to March incidence. Monthly averages for 32 years show that 90 per cent. of the total falls during this period.

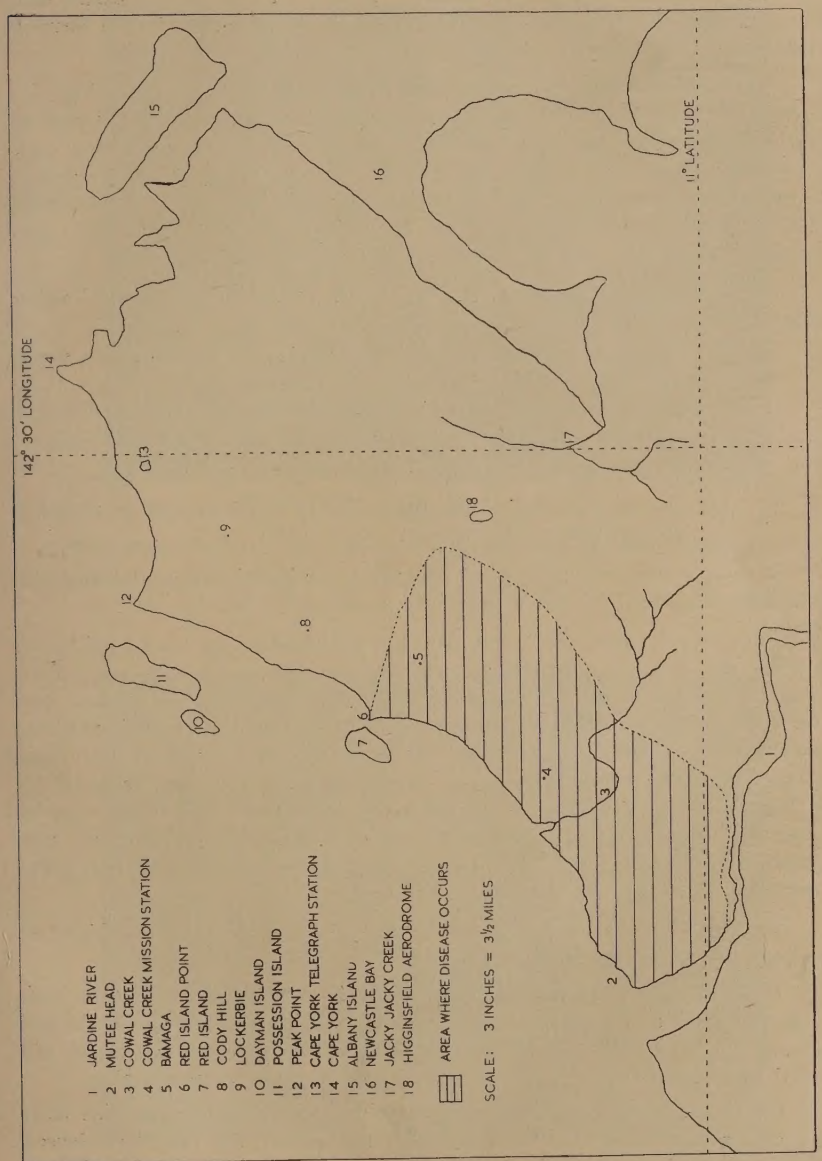

Fig. 1.

Distribution of "Change Hoof Disease" in the Bamaga Area.

Outbreaks of "change hoof disease" always occurred in the spring and early summer. The disease was confined to horses and only horses grazing certain areas were affected.

Most cases occurred in the Bamaga and Cowal Creek areas (Fig. 1). No cases occurred north of Red Island Point and consequently horses at Lockerbie and Cody Hill Stations were not affected. The vegetation over the whole area alternates between dense rain-forest and eucalypt forest country. The pasture at Bamaga was similar, but slightly inferior, to that at Lockerbie and Cody Hill. The striking botanical difference was that *M. reticulata* was very prevalent at Bamaga and was scarce on Lockerbie and Cody Hill.

Field evidence focused attention on *M. reticulata* for the following reasons:—

(*a*) In the area, pastures are burnt off in the spring and a rapid regrowth of *M. reticulata* follows early storm rains. It is succulent and relatively abundant at the period when outbreaks of the disease occur. It later becomes coarse and unpalatable.

(*b*) There was ample evidence that the plant had been grazed.

(*c*) The distribution of the plant closely followed that of recorded occurrences of the disease.

A sample from a mature plant was taken for identification and analysis. The sample contained 76 p.p.m. selenium in the dried plant.

Horses in the area were not under close supervision and loss of hair from the mane and tail was the first abnormality usually seen. Local experience was that horses were affected for several months. Most survived if food and water were readily available but some died during the acute phase of laminitis, probably due to inability to feed and reach water. In the majority of cases hoof shedding was a gradual process whereby the old hoof was replaced by new horn growing down from the coronet. Some cases had been reported to shed their hooves during the acute stage of laminitis. Horses of all ages and both sexes were affected and an attack apparently conferred no immunity, as certain horses had been affected twice or more.

At the time the area was visited three horses were affected, but all were past the acute stage of the disease.

Case 1.—This was a young unbroken filly whose front hooves each displayed a crack and transverse corrugations. The hind feet were normal and lameness had practically disappeared. Loss of hair from the mane and tail was evident. As this was a chronic mild case no samples were taken.

Case 2.—An aged bay mare was examined at Cowal Creek. This mare had shown symptoms earlier than the other two cases. All four feet showed evidence of previous laminitis, the front ones being more severely affected The near front hoof was in the process of being shed. Hair on the mane and tail was scanty. Hair from mane and tail contained 2·5 and 1·0 p.p.m. selenium respectively. The condition of this mare is shown in Figs. 2-5.

Fig. 2.

Front Hooves of Cowal Creek Mare, showing Transverse and Vertical Separation.

Fig. 3.

Hind Hooves of Cowal Creek Mare, showing Transverse Cracking.

Case 3.—An aged stallion in fair condition displayed a stilted gait and unnatural stance. All four hooves showed a prominent transverse separation just distal to the coronet. The wall of the hooves had transverse corrugations, while proximal to the separation new horn was beginning to grow down. The front feet were more severely affected. Most of the mane and a good deal of the brush of the tail had fallen out. This subject was autopsied. An affected front hoof is shown in Fig. 6. The visceral organs appeared normal but samples were taken for histopathological examination and for chemical analysis. No unusual abnormality was detected microscopically and the following levels of selenium were determined in tissues and organs:—

	p.p.m.
Liver	2·6
Mane	12·0
Tail	6·0
Hoof	6·8
Hoof	8·0

III. FEEDING TRIALS.

Trial 1.

In 1956, McGavin (unpublished Departmental report) fed an aged mare (weighing 972 lb.) 165 lb. of *M. reticulata* over a period of 56 days.

The plant fed early in the trial contained 25·5 p.p.m. selenium while that fed later contained only 1·5 p.p.m. selenium. In this trial the clinical syndrome was not produced, nor was any abnormality detected at autopsy or on histopathological examination, but analysis showed the following amounts of selenium in the animal's tissues:—

	p.p.m.
Muscle (psoas)	Nil
Heart muscle	Nil
Spleen	1·1
Kidney	4·0
Liver	3·2
Tail hair grown before experiment commenced	Nil
Tail hair grown during experiment	4·0
Hoof grown during experiment	2·0

Trial 2.

In 1957, *M. reticulata* was fed to an aged gelding in fair condition and weighing 826 lb. at the beginning of the experiment.

The plant used was identified by the Government Botanist as *M. reticulata* and was from the property of the Department of Native Affairs, Bamaga.

The leaves were stripped from the stems, minced finely and added to oaten chaff at first and later to bran, oaten chaff and ground limestone.

Symptoms were first noticed 56 days after feeding commenced by which time the animal had eaten 72 lb. of *M. reticulata* containing approximately 7·3 g. of selenium. During the following 26 days, 66 lb. of *M. reticulata* containing approximately 6 g. of selenium was eaten.

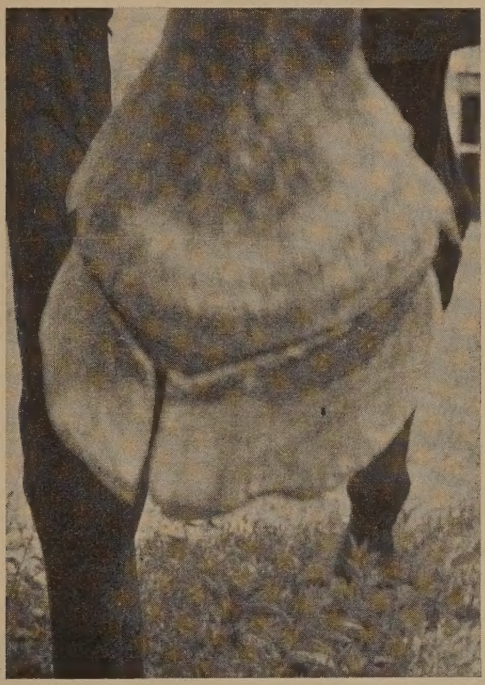

Fig. 4.

Close-up of Near-side Front Hoof of Cowal Creek Mare. Hoof in the process of being shed.

The first symptom was slight lameness in one hind foot. Four days later the horse was very lame in all four feet. It was frequently noted lying down, presumably in an attempt to ease its painful feet. When standing, the animal would place its forefeet close together and partially flex the hind limbs. Oedema was present over the ventral chest region one week after the first symptoms were seen. At this period the haemoglobin level fell from 15 g. to 12·6 g. per 100 ml. blood and the serum bilirubin rose to 2·0 mg. per 100 ml., which was the highest figure recorded during the trial.

Lameness was less marked two weeks after the animal was affected. Stranguria was noticed and was most evident when the animal was very lame.

The hoof formed during the trial was uneven, scaly and pale in colour. Horn development of all four feet was irregular for a distance of ½ in. to ¾ in. below the coronet. Distal to the abnormal horn there was a crack in the wall (Fig. 7).

A small amount of mane and tail hair was lost towards the end of the experiment. The remaining hair was fragile and broke near the skin when pulled. The animal was destroyed for autopsy on the 82nd day. The liver showed a few fibrinous tags on its parietal surface. These are common in aged horses in Queensland. The cartilage of the proximal articular surface of the left humerus was eroded, but microscopic examination did not show any inflammatory reaction of the adjacent bone. Microscopic examination of the haematoxylin and eosin stained sections of the cervical cord, thoracic cord, sciatic nerve, tibial nerve, lung, heart, spleen, adrenal and bladder did not show any abnormality. The Kupffer cells of the liver were more conspicuous than usual. In the kidney some of the glomeruli appeared swollen, completely occluding or narrowing the space between them and Bowman's capsule. However, these are common features of the liver and kidney of horses.

Analysis revealed the following amount of selenium in the tissues and organs of this animal at autopsy:—

	p.p.m.
Left lobe liver	8·6
Middle lobe liver	9·8
Left kidney	8·2
Right kidney	8·2
Spleen	2·0
Lung	0·8
Muscle (psoas)	2·9
Muscle (semitendenosis)	1·6
Blood	4·1
Left front hoof	11·4
Body hair grown during feeding	11·2
Mane hair grown during feeding	19·4
Tail hair grown during feeding	45·4

IV. LABORATORY FINDINGS.

The methods used in the analyses of soils, plant and animal tissues were those described by Trelease and Beath (1949).

Eleven samples of *M. reticulata*, taken from the area where the disease occurs (Fig. 1), were analysed. Selenium levels varied from 1·5 to 1,141 p.p.m. selenium on moisture-free plant material. Details of these findings are shown in Table 1.

Table 1.

SELENIUM CONTENT OF *Morinda reticulata*.

Specimen.	Time Collected.	Se Content as Received.	Se Content on Moisture-free Basis.	Remarks.
		p.p.m.	p.p.m.	
Old mature leaf	Dec. 1955	..	76.0	Composite sample
Fibrous leaf	Feb. 1956	16.3	25.5	Composite sample used in feeding trial 1
Fibrous leaf	Mar. 1956	0.7	1.5	,, ,, ,,
Old mature leaf	Jan. 1957	..	720	Used in feeding trial 2
Old mature leaf	Jan. 1957	..	610	,, ,, ,,
Old mature leaf	Mar. 1957	93	109	,, ,, ,,
Old mature leaf	Mar. 1957	201	259	,, ,, ,,
*Succulent young leaf ..	Nov. 1956	407	1,141	From a single plant
*Green mature leaf ..	Nov. 1956	320	422	From the same plant
*Old mature leaf	Nov. 1956	138	151	,, ,, ,,
*Rootstock	Nov. 1956	387	610	,, ,, ,,

* Soil samples in association with this plant were taken.

Two specimens from a single plant were used to assess the type of selenium compound in the plant. The results are given in Table 2.

Table 2.

TYPE OF SELENIUM COMPOUND PRESENT IN *Morinda reticulata*.

Sample.	Total Se.	Water Soluble Se.	Selenite Se.	Selenate Se.
	p.p.m.	p.p.m.	p.p.m.	p.p.m.
Green mature leaf	422	63.1	..	..
Old mature leaf	151	23.4	..	..

Fig. 5.
Tail of Cowal Creek Mare, showing Scant Hair on Butt of Tail.

The only other non-pasture species eaten to any extent when the disease occurs in *Breynia cernua*. A specimen of this plant growing in association with seleniferous *M reticulata* did not contain selenium.

Fig. 6.

Affected Front Hoof of Bamaga Stallion, showing Transverse Separation

The soils associated with *M. reticulata* in the Bamaga area are brown sandy loams overlying a reddish-brown loam to clay loam and are probably derived from the Blythesdale formation of freshwater sandstones of Lower Cretaceous age.

Four soil samples were taken from the Bamaga area. Selenium was detected only in a sample containing debris of *M. reticulata*. Analytical data are shown in Table 3.

Table 3.

SELENIUM CONTENT OF SOIL SAMPLES TAKEN FROM BAMAGA AREA.

Specimen.	Time Collected.	Se in Air-dried Soil.
		p.p.m.
Brown sandy loam from surface of area carrying scattered *M. reticulata* *	Dec. 1955	Less than 0.02
Red brown sandy loam containing dry plant debris from surface under plant of *M. reticulata* *	Nov. 1956	0.1 to 0.4, depending on amount of debris taken
Reddish-brown clay loam taken at 12 in. depth associated with root of *M. reticulata* *	Nov. 1956	Less than 0.01
Reddish sandy loam from surface not associated with *M. reticulata*	Nov. 1956	Less than 0.01

* Analysis of this plant is given in Table 1.

Fig. 7.

Hoof of Horse in 1957 Feeding Trial, showing Early Cracking.

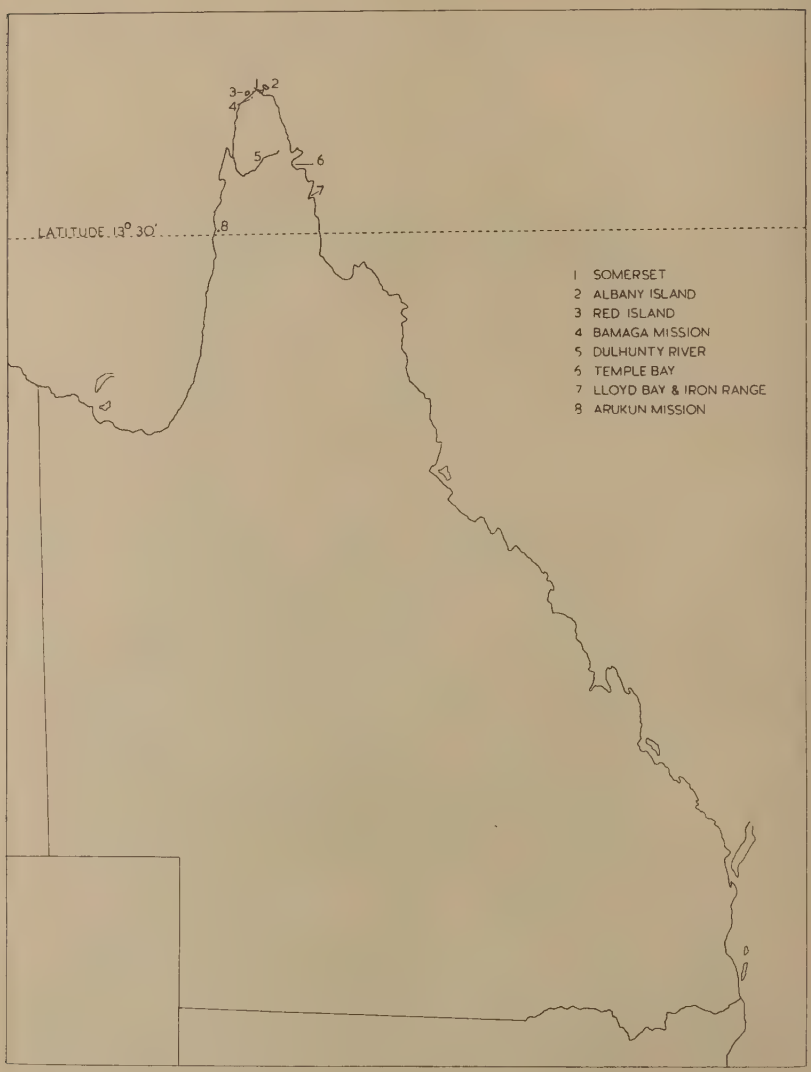

Fig. 8.

Distribution of *Morinda reticulata* as shown by Herbarium Specimens. Known distribution is confined to the Cape York area.

V. DISCUSSION.

The field evidence and feeding trials reported show that *M. reticulata* is the cause of "change hoof disease." Chemical analysis shows that the plant contains toxic levels of selenium and that the disease is chronic selenosis.

M. reticulata belongs to the family *Rubiaceae,* no member of which has been previously reported to contain selenium. Eight species of *Morinda* occur in Queensland, some widely distributed in populated areas. Two are rare, including *M. reticulata,* which is confined to Cape York Peninsula, as shown in Fig. 6. This distribution is based on specimens in the Queensland Herbarium but the region is not well known botanically and it is possible that future collection may extend the known range. The plant is a low, sparse bush, growing 1–3 ft. high, with several little-branched, pale-green stems arising from a much thickened, irregular-shaped, rather woody rootstock.

Clinical changes seen at Bamaga, involving laminitis, affected hooves and alopecia of the mane and tail, follow the classical pattern for chronic selenosis in horses.

Analytical data for tissues from the horse autopsied at Bamaga (hoof 8·0, mane 12·0, tail 6·0 p.p.m. selenium) are comparable with those recorded in other countries. Fleming and Walsh (1957) reported 9·3, 8·7, 7·5, 7·3, 7·1 and 6·2 p.p.m. in sloughed hooves, 12·7 p.p.m. in the mane, and 5·4 p.p.m. in the tail of a selenised pony in Ireland. A level of 8·0 p.p.m. selenium was recorded in the hoof of an "alkali horse" from South Dakota (Dudley 1936).

No lesions were evident either macroscopically or microscopically in the liver and kidney, but the autopsied horse was said to be "recovering" and some regeneration may have taken place. Analyses of leaves of *M. reticulata* showed a wide variation in selenium content, but young succulent leaves showed selenium levels much higher than old mature leaves. This suggests that the degree of exposure of stock to this source of selenium may be related to stage of growth of this plant. This would explain the seasonal nature of the disorder, the rapid onset of symptoms and the gradual recovery in affected horses.

Clinical symptoms were not produced in the 1956 feeding trial (Trial 1). Although 165 lb. of *M. reticulata* was fed to a horse over a period of 56 days, subsequent analyses showed that the selenium content of the plant fed initially was 25·5 p.p.m. and of that fed later 1·5 p.p.m. This lower level would not be expected to induce selenosis. The analyses of tissues and organs at autopsy showed significant levels of selenium.

Plant material used in the 1957 feeding trial gave a much higher level of selenium in the diet, and in the test animal a syndrome resembling that found in the field was produced. Comparison of the amount of selenium ingested (13·3 g.) with the levels in tissues and organs indicates that an appreciable amount of the selenium as it occurs in *M. reticulata* is absorbed and retained by horses eating this plant. The concentrations of selenium in the tissues, particularly the horn and hair formed during feeding (hoof 11·4, body hair 11·2, mane 19·2 and tail 45·4 p.p.m. selenium respectively) are

comparable with those in the naturally affected animal (hoof 8·0, mane 12·0, tail 6·0 p.p.m. selenium). The uneven pale and scaly horn produced, as well as the fragility of the mane and tail hair, compare with the symptoms produced by dosing horses with sodium selenite. Miller and Williams (1940) fed sodium selenite for a period of 17 months; 96 p.p.m. selenium in the ration was given for the last two months and 48 p.p.m. selenium for the previous 9 months. This produced death and lesions in the heart, liver and kidney resembling field cases seen in U.S.A. In the *M. reticulata* feeding trial the average selenium content of the ration (13·3 g. Se in 280 Kg. feed) was 47·5 p.p.m. fed for 82 days but no internal lesions were produced.

The break in the hoof was not as marked as in the natural case, but if the animal had been allowed to survive the affected hoof may have cracked as it grew down. Affected hooves from a natural case and the 1957 feeding trial are shown in Figs. 3 and 4.

It is probable that the production of abnormal horn began within a few days of commencing to feed *M. reticulata* but no lameness was noticed till the 57th day. This could be associated with the structure of the hoof. In the unaffected hoof there would be a normal distribution of pressure at the stratum germinativum of the hoof where new horn is being formed or this horn would be abnormally shaped. Trautmann and Fiebiger (1952) described how most of the horn of the hoof is formed by the coronary stratum germinativum and it might be expected that some time will elapse before affected horn has grown down sufficiently for its weakness to cause abnormal pressure on the sensitive underlying tissues. Moxan and Rhian (1943) stated that in cattle a drop in haemoglobin can be used to detect early cases of "alkali disease". In the feeding trial there was no conspicuous drop in the haemoglobin, but the lower haemoglobin and higher bilirubin on the 60th day could be associated with some loss of red cells.

The stranguria was probably due to the painful feet causing considerable discomfort when the animal attempted to assume normal urinating posture.

In attempting to assess the extent and nature of the problem at Bamaga only the broadest general conclusions can be drawn. The remoteness and isolation of the outbreak, the sparse population and the lack of detailed geological and botanical knowledge of the area have militated against a critical discussion of factors influencing "change hoof disease".

Information available indicates the following conclusions:—

(1) The common pasture species have no significant amount of selenium for the greater part of the year, since cattle are not affected and the occurrence of selenosis in horses is seasonal.

(2) The level of selenium in the soil samples analysed has been extremely low. This is in keeping with the suggestion of a selenium accumulator plant in association with a non-seleniferous pasture and resembles conditions

in "alkali" areas in U.S.A. In Ireland a high selenium content was recorded in all pasture species growing on soils rich in organic matter containing up to 1,200 p.p.m. selenium (Fleming and Walsh 1957).

(3) A level of total selenium in *M. reticulata* commonly in excess of 200 p.p.m. is higher than levels reported for most pasture species in Irish toxic areas where soil levels of selenium are high (Fleming and Walsh 1957), and much higher than levels reported for normal forage species in "alkali" areas in U.S.A. where soil levels of selenium are relatively low (Moxan and Rhian 1943). This suggests that *M. reticulata* may be classified as an "accumulator" plant. The fact that 15 per cent. of the selenium in dried mature leaves is in the form of water-soluble organic selenium suggests the plant as a selenium accumulator comparable with secondary selenium accumulators in U.S.A. (Trelease and Beath 1949).

(4) In contrast with "alkali" areas in U.S.A. the area where the disease occurs is one of high rainfall, but observations indicate it is unlikely that the source of selenium could be a water-soluble form accumulating in wet areas. Such a source was incriminated in Ireland (Fleming and Walsh 1957).

(5) The fact that the outbreaks at Bamaga and Arukun and an unconfirmed outbreak at Temple Bay were each locally associated with *M. reticulata* suggests this plant as the major cause of selenosis in Cape York Peninsula.

VI. ACKNOWLEDGEMENTS.

Our thanks are due to Mr. P. Killoran, Officer-in-Charge, Department of Native Affairs, Thursday Island, for arranging the visit to the area, to Mr. C. T. Holland of Lockerbie Station for information concerning the local condition, to the Superintendent and staff of the Bamaga Settlement for material used in feeding trials and samples of soil and plant material, and to Mr. L. S. Smith, B.Sc., Departmental Botanist, for information concerning the distribution of *M. reticulata*.

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STUDIES OF THE COCCOIDEA.

7. NEW DESIGNATIONS OF SOME AUSTRALIAN DIASPIDIDAE.

By A. R. BRIMBLECOMBE, M.Sc., Senior Entomologist, Division of Plant Industry.

SUMMARY.

Further revisionary work on Australian Diaspididae has enabled the establishment of three new genera—Eulaingia, Eugreeniella, **and** Alioides—**and** Remotaspidiotus **has been reinstated as a valid genus. New combinations are** Diaspidiotus loranthi **(Laing),** Clavaspis subfervens **(Green),** Clavaspis subcuticularis **(Green),** Pseudaonidia cingulata **(Froggatt),** Pseudaonidia dryandrae **(Fuller),** Chrysomphalus rubribullatus **(Froggatt),** Remotaspidiotus coralinus **(Froggatt),** Remotaspidiotus bossieae **(Maskell),** Remotaspidiotus cassiniae **(Brimblecombe),** Eulaingia stenophyllae **(Laing),** Greeniella truncata **(Green and Laing),** Monaonidiella bidens **(Green),** Eugreeniella pulchra **(Green) and** Alioides tuberculata **(Laing). The last two species belong to the tribe Diaspidini, the remainder to the tribe Aspidiotini.**

INTRODUCTION.

Further material for study has been made available from various Australian and overseas collections. This with local material has enabled the preparation of enlarged descriptions and the determination of correct designations in the light of modern classifications.

Diaspidiotus loranthi (Laing) new combination.

(Figs. 1 and 2.)

Synonymy.

1929: *Aspidiotus loranthi* Laing; Bulletin of Entomological Research, 20: p. 21.

Type locality and host.—Victoria: Eltham, on *Loranthus pendulus.*

Material examined.—Queensland: Forest Hill, on *Loranthus pendulus* Sieb., Sept. 1938. New South Wales: Narrabri, on *Loranthus* sp., Oct. 1924 (W.W.F.). Victoria: Stawell, on *Loranthus* sp., 1920 (C. French), and Beechworth, on *Loranthus pendulus,* Dec. 1921 (C. French).

Habit.—Insects numerous on twigs of host. Female scale circular, mostly 1·5 mm. in diameter, convex, dark brown to blackish brown; pellicles dark orange to reddish brown.

Recognition characters.—Body of adult female oval to subcircular, membranous, length of slide specimen 1·3 mm., width 1·0 mm. Pygidium broad, apically broadly obtuse. Median pair of lobes only, broad basally, wider than long; margins curved, with an external large subapical indentation; apex broadly rounded; separated by one-fifth of a lobe's width. A small derm

Fig. 1.

Diaspidiotus loranthi. Outline of Body. × 65.

Fig. 2.

Diaspidiotus loranthi. Enlargement of Pygidium. × 265.

projection only in the second lobe position. Basal scleroses absent. Paraphyses as prominent pairs in the first and second interlobal areas. Plates in the first, second and third interlobal spaces; two in the first space, spine-like, shorter than the lobes; three in the second space, linear, mostly simple, longer than the lobes; three or four similar plates in the third space. Spines adjacent to the lobes short, others longer than the lobes. Dorsal ducts of moderate length, slender, slightly longer than the distance from the lobes to the anal opening in the first furrow; orifices in segmental series, two in the first duct furrow between the paraphyses, seven in the second furrow, and six in the third furrow. Perivulvar pores absent. Anal opening small, four times its long axis from the bases of the lobes. Median and lateral dorsal pygidial scars prominent, subequal in length. Slight longitudinal chitinous striations on the pygidium.

Note.—Plates in the second and third interlobal spaces may sometimes be apically branched.

The position of this species in the genus *Aspidiotus* is untenable. Laing (1929) suggested that it might belong to *Hemiberlesia,* but the presence of median lobes only, the small anal opening, and the disposition of the plates, ducts and paraphyses are in agreement with the genus *Diaspidiotus,* in which it shows some relationship to *D. uvae* (Comstock) and *D. crystallinus* Ferris.

Clavaspis subfervens (Green) new combination.

(Figs. 3 and 4.)

Synonymy.

1904: *Aspidiotus* (*Targionia*) *subfervens* Green; Victorian Naturalist, 21: p. 66.

1921: *Monaonidiella subfervens* (Green): MacGillivray; The Coccidae, p. 446.

1929: *Targionia subfervens* (Green): Laing; Bulletin of Entomological Research, 20: p. 28.

Type locality and host.—Victoria: on *Acacia* sp.

Material examined.—Queensland: Laidley, on *Acacia harpophylla* F. Muell. ex Benth., Feb. 1900 (H. Tryon). Victoria: Warrandyte, on *Acacia melanoxylon* R.Br., 1922 (C. French).

Habit.—Insects scattered on twigs. Female scale blackish brown, pellicles reddish brown, convex, diameter 1·25 mm.

Recognition characters.—Adult female broadly turbinate, membranous, length of slide specimen 1·0 mm., width 0·8 mm. Pygidium broad, with median pair of lobes only. Lobes wider than long, convergent, almost contiguous apically; inner margin concave; outer margin broadly curved with a large lateral indentation; apex rounded. Basal scleroses arising from the inner basal part of the lobes subequal in length with the lobes. Paraphyses in the first and second interlobal areas, long and apically enlarged in both areas.

Fig. 3.

Clavaspis subfervens. Outline of Body. × 90.

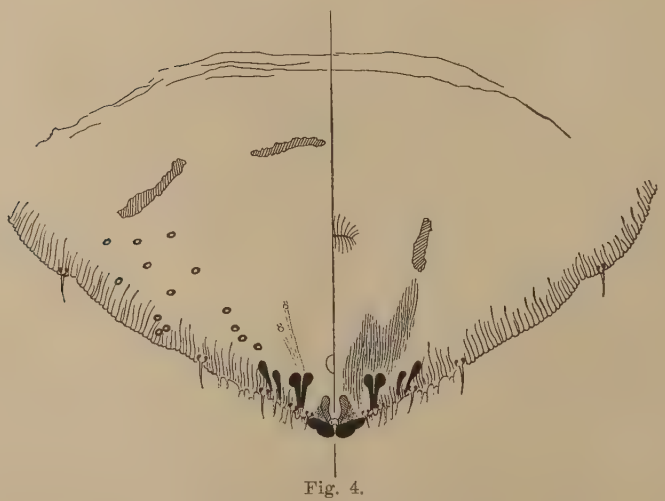

Fig. 4.

Clavaspis subfervens. Enlargement of Pygidium. × 195.

Plates in the first, second and third interlobal spaces; two in the first, short and simple; three in the second, shorter than the adjacent spines, simple, or one or two may be once-branched; three in the third each mostly as a pair of fine divergent arms on a raised base. Spines adjacent to the lobes shorter than the lobes, other spines longer. Dorsal ducts sparse, slender, length in the first duct furrow two-and-a-half times the distance from the median lobes to the anal opening; two in the first duct furrow; four to six in the second furrow other than those with orifices between the paraphyses, one or two separated in an anterior position, three or four as a group in a row nearer the paraphyses; five or six in the third furrow, evenly spaced or as three or four in an anterior group and one or two nearer the margin; a few marginal ducts on anterior segments to the position of the thoracic tubercle. Perivulvar pores absent. Anal opening oval, smaller than a median lobe, distance from apices of basal scleroses equal to the combined length of a median lobe and basal scleroses. Pygidium with median and lateral scars, and longitudinal chitinous striations. A small dome-shaped thoracic tubercle is evident on some specimens.

Notes.—The raised bases of the plates in the third interlobal space are not always apparent; suggestions of them are evident in the illustration given by Laing (1929). The apically enlarged paraphyses, the disposition and size of the ducts, and the prominent median lobes are typical characters of the genus *Clavaspis*. This species resembles *C. subsimilus* Ckll. but differs in having apically contiguous lobes.

Clavaspis subcuticularis (Green) new combination.

(Figs. 5 and 6.)

Synonymy.

1916: *Aspidiotus* (*Aonidiella*) *subcuticularis* Green; Bulletin of Entomological Research 7: p. 54.

1921: *Aonidiella subcuticularis* Green: MacGillivray; The Coccidae, p. 444.

Type locality and host.—Northern Territory: Darwin, on *Ficus orbicularis*.

Material examined.—"*Aspidiotus subcuticularis* n.sp., *Ficus orbicularis*, Darwin, N.T., I.B.E. 23, Hill Coll."

Habit.—Female insects single and sparse, embedded within the leaf tissue with only the apex of the dark brown pellicle exposed. Scale dense and brittle, invariably damaged with extraction of insects.

Recognition characters.—Adult female broadly pyriform to subcircular, membranous, length of slide specimen 0·7 mm., width 0·6 mm. Pygidium broad with two pairs of lobes. Median lobes triangular, twice as wide as long; inner margins almost contiguous basally, widely divergent apically; outer margin with a deep lateral indentation; apex rounded. Second pair of lobes as small, broad, triangular, chitinized points. Basal scleroses arising from the inner

Fig. 5.

Clavaspis subcuticularis. Outline of Body. × 110.

Fig. 6.

Clavaspis subcuticularis. Enlargement of Pygidium. × 300.

basal portion of the median lobes, as long as the lobes. Paraphyses in the first interlobal area long and apically enlarged, longer than the combined length of the median lobes and basal scleroses; a pair in the second interlobal area, two-thirds the length of those in the first area, the outer more clubbed than the inner. Plates in the first, second and third interlobal spaces; two in the first space shorter than the second pair of lobes; two in the second space simple, curved, shorter than adjacent spines; two or three in the third space as short broad cones surmounted by one or two slender branches. Spines adjacent to the median lobes shorter than these lobes, other spines longer. Dorsal ducts sparse, slender; length in the first furrow two-and-a-half times the distance from the bases of the lobes to the anal opening; orifices inconspicuous, two in first duct furrow between the paraphyses, possibly four or five widely spaced in the second furrow excluding those between the paraphyses, possibly five in the third furrow with a few short marginal ducts on anterior and thoracic segments to the thoracic tubercle. Perivulvar pores absent. Anal opening very small, as far from the basal scleroses as the combined length of the median lobes and basal scleroses. Pygidial lateral and median scars prominent, median pair joined. A short sharp marginal tubercle on the thorax.

Notes.—The long paraphyses place this species near *C. subfervens* (Mask.) but it differs from that species in the divergent median lobes and the small second pair of lobes. The subcuticular position in the host leaf is an outstanding feature with this insect.

Pseudaonidia cingulata (Froggatt) new combination.

(Figs. 7 and 8.)

Synonymy.

1914: *Aspidiotus cingulatus* Froggatt; Agricultural Gazette of New South Wales, 25: p. 135.

Type locality and host.—Victoria: Lake Albacutya, on *Casuarina* sp.

Material examined.—Victoria: Lake Albacutya, on *Casuarina* sp. (C. French) labelled "*Aspidiotus cingulatus* Green n.sp., part type," and from the same locality labelled "*Aspidiotus cingulatus* Frogg.". New South Wales: "Leeton, on *Casuarina* sp., 28.8.1916, McKeown." Queensland: Forest Hill, on *Casuarina cristata* Miq., Dec. 1937.

Habit.—Insects singly on branchlets of host. Female scales convex to conical, basally curved round the branchlet, 2·5 to 3·0 mm. in length, colour fawn; second pellicle whitish, surmounted by the yellow first pellicle.

Recognition characters.—Adult female with a large thoracic constriction; anterior portion dome-shaped; posterior portion wider, shield-shaped, apically broadly rounded; length of slide specimen 2·0 mm., width 1·75 mm. Pygidium

Fig. 7.

Pseudaonidia cingulata. Outline of Body. × 40.

Fig. 8.

Pseudaonidia cingulata. Enlargement of Pygidium. × 155.

broad, not differentiated, with four pairs of lobes. Median lobes wider than long, slightly constricted basally, apex broadly rounded, separated by half a lobe's width. Second pair of lobes similar to the median, and subequal to these in size, separated from the median lobes by one-third of the latter's width. Third pair of lobes similar to the second pair, but smaller, without the basal constriction and the outer margin more broadly curved, separated from the second pair by almost the latter's width. Fourth pair of lobes broad, short and rounded. Margin of fifth and fourth abdominal segments serrate. Basal scleroses absent. Paraphyses in the median, first, second and third interlobal areas; a pair in the median area, short and stout; the inner paraphyses of the pair in the first, second and third interlobal areas, subequal in size, longer than the median lobes, apically slightly enlarged; the outer paraphyses in these areas not strongly developed. Plates in the median first and second interlobal spaces; two in each, as long as the lobes, slender and apically branched. Spines shorter than lobes near the median, second and third pairs of lobes, others as long as the lobes or longer. Dorsal ducts very numerous, length in the median area about half the distance from the lobes to the anal opening, orifices in segmental series, 12 in the median interlobal area, 12 to 15 in the first duct furrow, crowded in the second furrow and progressively more numerous on other abdominal segments. Perivulvar pores in five groups; two pores in the anterior group, eight or nine in the anterior lateral groups and four to six in the posterior lateral groups. Anal opening small, one-third of the distance of the anterior perivulvar pores from the lobes. Pygidium dorsally with reticulate chitinization over an oval area, remainder of body heavily chitinized. Spiracles small, anterior pair with eight to 12 associated pores.

Notes.—The more numerous dorsal ducts and the presence of perivulvar pores are characters separating this species from other Australian species in the genus. The perivulvar pores may sometimes appear as a continuous arch instead of as groups.

Material of this species was examined and labelled but not described by Mr. E. E. Green of the British Museum. Froggatt's description established the species and reference by him to Green as the authority is erroneous.

Pseudaonidia dryandrae (Fuller) new combination.

(Figs. 9 and 10.)

Synonymy.

1897: *Aspidiotus dryandrae* Fuller: Journal of the Bureau of Agriculture, Western Australia 4: p. 1344.

1921: *Targaspidiotus dryandrae* (Fuller): MacGillivray; The Coccidae: p. 447.

Type locality and host.—Western Australia: Swan River, on *Dryandra floribunda.*

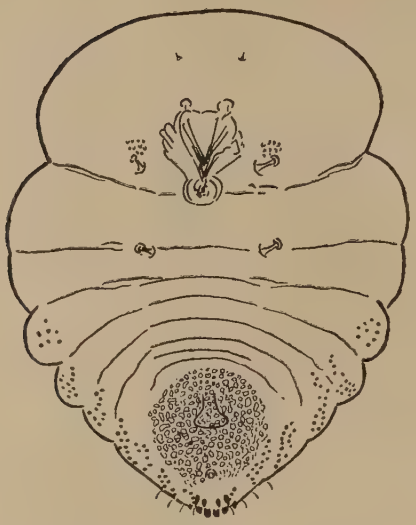

Fig. 9.

Pseudaonidia dryandrae. Outline of Body. × 70.

Fig. 10.

Pseudaonidia dryandrae. Enlargement of Pygidium. × 185.

Material examined.—From the United States National Museum a slide labelled "*Aspidiotus dryandrae* Fuller, type."

Recognition characters.—Adult female oval in general shape, length of slide specimen 1·25 mm., width 0·95 mm., body divided by a deep thoracic constriction; anterior portion dome-shaped, less than twice as wide as long; posterior portion wider than long, sides curved, with anterior abdominal segmental constrictions. Pygidium not differentiated, broad, apex obtuse; four pairs of lobes. Median lobes as wide as or slightly wider than long, slightly constricted basally, separated by less than a quarter of the lobes width; inner and outer margins curved, each with a subapical indentation; apex broadly rounded or with an indentation. Second pair of lobes shorter than the median pair, length and width subequal, margins slightly curved with an outer subapical large indentation, apex round, separated from the median lobes by a quarter of the latter's width. Third pair of lobes smaller than the second pair, as wide as long, almost conical, apex pointed, separated from the second pair by one to one-and-a-half times the width of the median lobes. Fourth pair of lobes small conical points, sometimes not obvious, closer to the third pair than the third to the second. Basal scleroses absent. Paraphyses on the inner side of the first and second interlobal areas, as long as the median lobes, club-shaped but not with a terminal knob. Plates absent in the median and first interlobal spaces; as two small subequal conical derm projections in the second interlobal space. Dorsal ducts short, on all abdominal segments, orifices normal, seven in the first duct furrow, 11 or 12 in the second furrow, about 10 in the third. Perivulvar pores absent. Anal opening small, less than one-third the length of the pygidium from the median lobes. Pygidial margin beyond the fourth pair of lobes entire. A broad central pear-shaped area of reticulate chitinization dorsally on the pygidium. Entire body chitinized. Anterior spiracles with 10 to 17 associated pores.

Notes.—The constricted thorax, four pairs of lobes, dorsal pygidial reticulate chitinization and the nature and distribution of the ducts and duct orifices are regarded as characters which suggest that this species belongs to the genus *Pseudaonidia*. A comparison of this species with the illustration of the genotype of *Targaspidiotus* as given by Ferris (1937 (b) p. 100), (See also 1938, p. 44) shows that its reference to this genus by MacGillivray (1921) was not correct. The description first given by Fuller (1897) was terse; a full description was given later (Fuller 1899).

Chrysomphalus rubribullatus (Froggatt) new combination.

(Figs. 11 and 12.)

Synonymy.

1897: *Aspidiotus perniciosus* var. *eucalypti* Fuller; Journal of the Bureau of Agriculture, Western Australia, 4: p. 1344.

1899: *Aspidiotus* (*Diaspidiotus*) *perniciosus* var. *eucalypti* Fuller: Cockerell; Illinois State Laboratory of Natural History, 5: p. 396.

1914: *Aspidiotus* (*Aspidiella*) *rubribullata* Froggatt; Agricultural Gazette of New South Wales, 25: p. 317.

1916: *Aspidiotus* (*Aonidiella*) *miniatae* Green; Bulletin of Entomological Research, 7: p. 53.

1921: *Neosignoretia miniatae* (Green): MacGillivray; The Coccidae: p. 424.

1941: *Diaspidiotus eucalypti* (Fuller): Ferris; Microentomology, 6: p. 43.

1941: *Quadraspidiotus rubribullata* (Froggatt): Ferris; Microentomology, 6: p. 48.

Type localities and host.—Western Australia: near Perth, on *Eucalyptus* sp. New South Wales: Trangie, on *Eucalyptus* sp.

Material examined.—

(i.) From New South Wales Department of Agriculture, labelled—

(*a*) "*Aspidiotus rubribullata, Eucalyptus* sp., Perth, W.A., 21.5.00."

(*b*) "*Aspidiotus rubribullata, Eucalyptus* sp., Perth, W.A., 11.7.00 (Wickens)."

(*c*) "*Aspidiotus rubribullata, Eucalyptus,* Trangie, N.S.W., 6.7.10, W.W.F."

(ii.) From United States National Museum, labelled "*Diaspidiotus eucalypti* (Fuller), Ckll. Coll. type," allegedly from type material.

(iii.) From Western Australian Department of Agriculture labelled "*Aspidiotus eucalypti*" allegedly left by Fuller.

Fig. 11.

Chrysomphalus rubribullatus. Outline of Body. × 150.

(iv.) From South Australian Museum labelled "*Aspidiotus miniatae* Green, *Eucalyptus miniata*, Darwin, N.T., Hill. coll, part of type material."

(v.) Queensland Department of Agriculture and Stock, labelled "West. Australia on *Eucalyptus* sp. 1910, H.T."

(vi.) From C.S.I.R.O., Canberra, labelled—

(*a*) "*Aspidiotus acaciae* var. *propinqua, E. macrocarpa,* Western Australia, 1912, No. 12, Newman."

(*b*) "*Aspidiotus acaciae* var. *propinqua, Eucalypt. macrocarpa,* Claremont, W.A., No. 10, Newman."

(*c*) "*Aspidiotus acaciae* var. *propinqua, Eucalyptus,* Claremont, West. Aust. 1529, Newman."

(*d*) "*Aspidiotus* sp. Mallee, Vict."

(*e*) "*Eucalyptus* sp., Mallee, Victoria, C. French, 1919."

(*f*) "Victoria, Hattah, Mallee, J. E. Dixon, 1919."

(*g*) "*Aspidiotus miniatae* Green, n.sp. *Eu. miniata,* Darwin, N.T., G. F. Hill, Paratype material, I.B.E., List. No. 18."

(*h*) "*Eucalyptus transcontinentalis,* Euston, N.S.W., 25.10.28."

Habit.—Insects numerous on twigs and small branches. Scale convex and mostly circular, varying in size to 1·25 mm. diameter, dark brown in colour with a fawn margin. First and second pellicles central, with a pale grey flaky covering weathering to expose the dark orange colour of the pellicles.

Fig. 12.

Chrysomphalus rubribullatus. Enlargement of Pygidium. × 220.

Recognition characters.—Adult female oval to subcircular, length of slide specimens to 0·75 mm., width to 0·6 mm., prosoma varying from membranous to moderately chitinized. Pygidium broad basally, with longitudinal chitinous striations, and three pairs of normal lobes. Median lobes as wide or slightly wider than long, base sometimes slightly constricted; separated by one-third of a lobe's width; inner margins subparallel to each other, sometimes with a subapical indentation; outer margin curved with a large latero-apical indentation; apex broadly rounded. Second pair of lobes smaller than the median, wider than long, separated from the median by half the latter's width, inner margins subparallel to each other, outer margins convergent to the inner, with one or two indentations sometimes finely serrate, apex rounded. Third pair of lobes triangular, twice as wide as long, outer margin finely indented, almost serrate, separated from the second by more than the width of a median lobe. Fourth pair of lobes developed, triangular, indented or finely serrate on the outer margin, as far from the third pair of lobes as these are from the median pair. Basal scleroses absent. Paraphyses as a slightly divergent pair in the median, first and second interlobal areas; the pair in the first interlobal area longer than the median lobes. Plates in the median interlobal area small and simple; two plates in the first interlobal space, slender, almost as long as the lobes, one apparently simple, the other apically branched; three plates in the second interlobal space, slender, slightly longer than the lobes, one or two may be simple or branched, the third wider, once or twice branched; three plates in the third interlobal space, each on a broad base and with a pair of simple widely divergent arms. Spines short. Macroducts long, in the first furrow twice the distance from the median lobes to the anal opening; orifices of moderate size, four to six in the first duct furrow, at least four within the paraphyses; 10 to 14 in the second furrow; 11 or 12 in the third furrow; three or four submarginally on the fourth abdominal segment, one or none submarginally on the third segment, several shorter and smaller ducts nearer the margin on the third, second and first abdominal segments and anterior almost to the position of the thoracic tubercle. Perivulvar pores absent. Lateral and median scars present. Anal opening small, smaller than the second lobe, three to four times the length of the median lobes from the base of the lobes; an anal groove present. Thoracic tubercle small, short, apex serrate.

Notes.—The material loaned by the New South Wales Department of Agriculture is regarded as type material of *Aspidiotus rubribullata* Froggatt and the recognition characters given above are mainly from this material.

The many specimens examined show much variation. Young adult females are mostly broadly pyriform to oval and unchitinized. Older specimens may be subcircular to subreniform and heavily chitinized. The third lobe may be triangular and the fourth lobe only a triangular point. No marginal chitinization occurs anterior to this lobe. Submarginally on the fourth

abdominal segment the number of longer ducts may vary from one to eight, and on the third segment from none to four although mostly one or none. A fourth plate may occur in the third interlobal space. The plates in this space may be slender or broad, sometimes with a short conical projection between the divergent arms. The third plate in the second interlobal space may be four-branched. Sometimes the anal opening may be as close as three times the length of the median lobes from the bases of the lobes and the thoracic tubercle may not always be distinct.

The body chitinization, slight enlargement of the prosoma, the fourth lobe structure and the comparatively broad ducts are characters suggesting that this species belongs to the genus *Aonidiella*. These characters, together with the membranous body and pyriform shape, the shape of the thoracic tubercle, the presence of the fourth lobe-like structure and the long ducts and submarginal macroducts on abdominal segments, are in agreement with the genus *Chrysomphalus*. Sometimes the lobes, especially on specimens in which the fourth lobe-like structure is not noticeable, and the plates resemble those of *Quadraspidiotus*.

The species when described by Fuller was placed as a variety of *Aspidiotus perniciosus* Comst., which is now in the genus *Quadraspidiotus*, to which it has some resemblance, but the detailed structure is more in agreement with the genus *Chrysomphalus*.

Maskell (1896) apparently examined material of this species taken on *Eucalyptus corynocalyx* from Adelaide, stating, "I have placed this insect in my cabinet with the label *A. perniciosus* var. but I will not add the word *eucalypti*." Fuller (1897, 1899) used the name *Aspidiotus perniciosus* var. *eucalypti* but expressed the fear that his variety might be the same as *Aspidiotus eucalypti* var. *comatus* Maskell. *A. eucalypti* Maskell is now known as *Neomorgania eucalypti* (Maskell) (Brimblecombe 1954) and *A. eucalypti* var. *comatus* Maskell is now *Pseudotargionia comatus* (Maskell) (Brimblecombe 1954).

Specimens from the part-type material of *Aspidiotus* (*Aonidiella*) *miniatae* Green from the South Australian Museum have been compared with the type in the British Museum. The former have been compared with "*Diaspidiotus eucalypti* Fuller type" from the United States National Museum and these two series with *Aspidiotus rubribullata* Froggatt, which are regarded as part of the type material.

This species is closely related to *C. ficus* Ashmead and *C. bifasciculatus* Ferris in having submarginal ducts on prepygidial abdominal segments, but it differs from these species in the absence of perivulvar pores.

Genus **Remotaspidiotus** MacGillivray.

1921: *Remotaspidiotus* MacGillivray: The Coccidae, p. 391.

Generic type.—Aspidiotus (*Targionia*) *chenopodii* Marlatt.

Recognition characters.—Adult female membranous, broadly pyriform to oval, median pair of lobes only, mostly truncated, basal scleroses present, paraphyses absent, plates in the median first and second interlobal spaces, dorsal ducts mostly short, perivulvar pores absent, vulva anterior to anal opening, the first and second interlobal spaces are body indentations.

Notes.—The genus *Remotaspidiotus* was established to accommodate the generic type which is Australian and the American species *Aspidiotus dearnessi* Cockerell.

The generic type of the genus *Rhizaspidiotus* MacGillivray was found to be a synonym of *Aspidiotus dearnessi,* which therefore became the generic type of this genus (Ferris 1937 a). *Remotaspidiotus* was at the same time (Ferris 1937 a) stated to be a synonym of *Rhizaspidiotus* and *Aspidiotus chenopodii* thus became congeneric with various overseas species in *Rhizaspidiotus.* Other Australian species have since been found to be congeneric with *A. chenopodii* and differing from the overseas species. *Remotaspidiotus* therefore is now reinstated as a valid genus containing a group of Australian species.

This genus bears some relationship to *Aspidiella* as originally illustrated by Ferris (1937 b) but it differs in having only the median pair of lobes and no perivulvar pores. The differences are greater in a recent illustration of Chinese material of the generic type (Ferris 1955).

There is also some resemblance to the genus *Monaonidiella,* which has median lobes only and these have basal scleroses, but it has perivulvar pores (though few) and the plates are not in marginal indentations.

Remotaspidiotus cassiniae (Brimblecombe) new combination.

Synonymy.

1956: *Rhizaspidiotus cassiniae* Brimblecombe; Queensland Journal of Agricultural Science, 13: p. 121.

***Type** locality and host.*—Queensland: Inglewood, on *Cassinia laevis* **R. Br., Feb. 1954.**

This species was recently described and figured (Brimblecombe 1956).

Remotaspidiotus chenopodii (Marlatt).

(Figs. 13 and 14.)

Synonymy.

1908: *Aspidiotus* (*Targionia*) *chenopodii* Marlatt; United States Department of Agriculture, Technical Series 16, Part 2, p. 24.

1921: *Remotaspidiotus chenopodii* (Marlatt): MacGillivray; The Coccidae: pp. 394, 434.

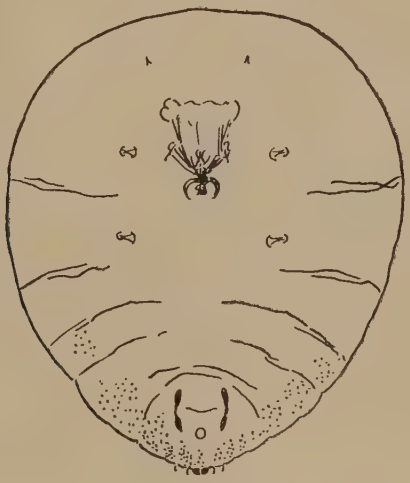

Fig. 13.

Remotaspidiotus chenopodii. Outline of Body. × 70.

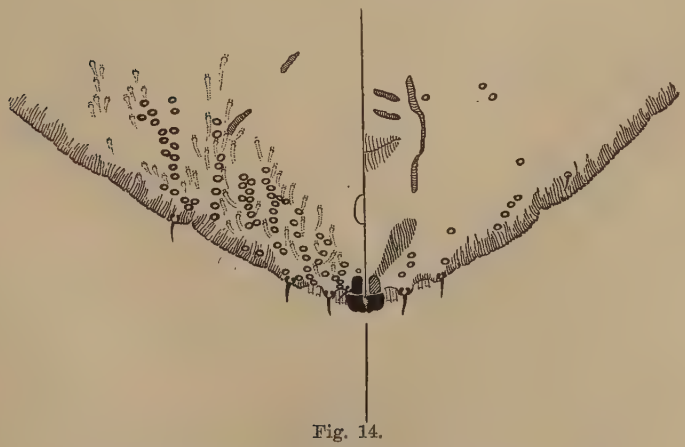

Fig. 14.

Remotaspidiotus chenopodii. Enlargement of Pygidium. × 205.

1937: *Rhizaspidiotus chenopodii* (Marlatt): Ferris; Microentomology: 2: p. 34.

Type locality and host.—New South Wales: Coolabah, on *Chenopodium* sp.

Material examined.—(*a*) "*Asp.* (*Targionia*) *chenopodii* Marlatt, on *Chenopodium*, Coolabah, N.S.W." (*b*) Queensland: Meandarra, on *Bassia quinquicuspis* F. Muell. var. *villosa* Benth., Oct. 1950.

Habit.—Insects scattered or clustered on branches of host. Scale of adult female white, subcircular, convex, diameter 1·2 to 1·75 mm.; pellicles pale yellow, partially covered with white suffusion.

Recognition characters.—Adult female broadly oval, membranous, length of slide specimen 1·0 mm., width 0·7 mm. Pygidium broadly obtuse. Median lobes only, length and width subequal, apically contiguous, basally separated by less than one-quarter of the lobe width; inner and outer margins almost parallel, inner margin concave, outer convex; apices broadly truncated with margins concave and slightly convergent, inner apical angles acute but rounded. Basal scleroses as long as but narrower than the lobes. Paraphyses absent. Plates in the median first and second interlobal spaces; two in the median space, simple, as long as the lobes; two in the first interlobal space, shorter than the lobes, apically bifid; two similar plates in the second interlobal space. Spines longer than the lobes. Macroducts short and slender, in discernible series with irregularly placed intermediate ducts; orifices normal, five or six in the first furrow, eight to 10 in the second, and a greater number in the third. Perivulvar pores absent. Anal opening large, two-and-a-half times its length from the bases of the lobes. Paravulvar folds long, slender, curved. Pygidial margin slightly indented.

Notes.—The irregular distribution of the macroduct orifices between the normal segmental series makes the determination of the number actually in the duct furrows difficult. The plates in the second interlobal space are not distinct in some specimens and apparently were missed by Marlatt. The projections representing the second and third lobes of Marlatt (1908) are derm and not lobes. Some specimens have a small dome-shaped thoracic tubercle.

Remotaspidiotus coralinus (Froggatt) new combination.

(Figs. 15 and 16.)

Synonymy.

1914: *Aspidiotus* (*Targionia*) *coralinus* Froggatt; Agricultural Gazette of New South Wales, 25: p. 136.

Type locality and host.—New South Wales; near Bourke, on *Eremophila sturtii.*

Material examined.—New South Wales: Bourke, on *Eremophila sturtii* R.Br., 1912 (per L. S. Smith). Queensland: Eulo, on *Eremophila sturtii*, Oct. 1954 (L. S. Smith).

Habit.—Insects numerous on leaves and twigs. Scales circular 1·2 mm. in diameter, white, convex; pellicles orange yellow.

Recognition characters.—Adult female membranous, subcircular, length of slide specimen 0·8 mm., width 0·75 mm. Pygidium broad with median pair of lobes only. Lobes wider than long; apex broadly curved; inner and outer margins subparallel, each slightly concave near base. Basal scleroses narrower but longer than the lobes. Paraphyses absent. Plates in the median, first and second interlobal spaces; two in the median, as long as the lobes, slender and simple; two in the first space, as long as the lobes, the inner one narrow and simple or once branched, the outer broader with latero-apical slender branches; possibly two plates in the second interlobal space (see notes). Spines longer than the lobes. Dorsal macroducts short, less in length than the distance from the bases of the lobes to the anal opening; orifices moderately large with chitinized rims, in segmental series; one in the median interlobal area; two or three in the first duct furrow, one or two between the first and second furrows; four or five in a marginal group and one or two submarginally in the second furrow; six to eight in the third furrow; about 11 in the fourth furrow; ducts becoming narrower and duct heads smaller on anterior abdominal segments. Ventral ducts and orifices similar to dorsal ducts. Perivulvar pores absent. Anal opening oval, smaller than a median lobe, twice the length of its long axis from the bases of the lobes, and one-third of the distance from the lobes to the vulva. Paravulvar folds long, narrow and conspicuous. Median and lateral dorsal pygidial scars co-linear and oblique to the median line. Spiracles small. A broad, low, dome-shaped marginal thoracic tubercle may be apparent laterally to the anterior spiracles.

Fig. 15.

Remotaspidiotus coralinus. Outline of Body. × 90.

Fig. 16.

Remotaspidiotus coralinus. Enlargement of Pygidium. × 250.

Notes.—Slight thickenings may occur in the first and second interlobal areas but are associated with duct orifices and are not paraphyses. The plates in the second interlobal space are not clearly defined in the specimens, and it is assumed that like *R. chenopodii* (Marl.) there are two, which may be broad with slender latero-apical arms. The lobes of some specimens show a slight latero-apical concavity or indentation but this species has not the truncated lobes of *R. chenopodii,* and not as many dorsal macroducts.

The type and type material of *Aspidiotus coralinus* Froggatt have not been located. The present material, being from the type locality and host and agreeing with the description, is considered to be correctly assigned to this species.

Remotaspidiotus bossieae (Maskell) new combination.

(Figs. 17 and 18.)

Synonymy.

1892: *Aspidiotus bossieae* Maskell; Transactions of the New Zealand Institute, 1891, 24: p. 10.

1897: *Hemiberlesia bossieae* (Maskell): Leonardi; Rivista di Patalogia Vegetale, 6: p. 122.

1941: *?Aspidiella bossieae* (Maskell): Ferris, Microentomology, 6: p. 41.

Type locality and host.—"Australia, on *Bossiea procumbens.*"

Material examined.—(*a*) A slide labelled "*Aspidiotus bossieae,* adult females, (Australia) 1891, W.M.M." stated to be the type, and unmounted specimens from the type material.

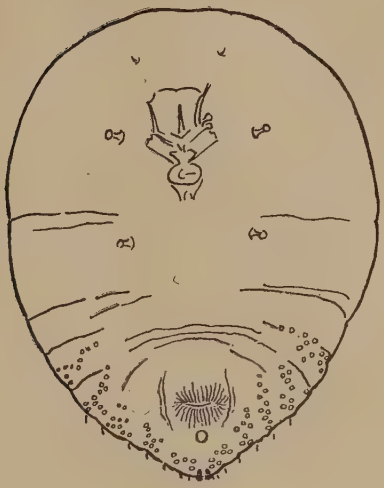

Fig. 17.

Remotaspidiotus bossieae. Outline of Body. × 70.

Fig. 18.

Remotaspidiotus bossieae. Enlargement of Pygidium. × 185.

Habit.—Insects in small groups on leaves of host. Scale of adult female white, circular, convex, diameter 1·75 mm.; pellicles central, pale orange with white suffusion.

Recognition characters.—Adult female broadly pyriform to oval, length of slide specimen 1·1 to 1·4 mm., width 0·8 to 1·2 mm. Pygidium broadly obtuse. Median pair of lobes only, slightly wider than long, separated by half a lobe's width; inner and outer margins almost parallel; apices broadly rounded to truncated. Basal scleroses as long as but narrower than the lobes. Paraphyses absent. Plates in the median, first and second interlobal spaces; two in the median space, slender, as long as or longer than the lobes; two in a large indentation in the first interlobal space, one appears to be three-branched, as long as the lobes; one and possibly two plates in the second interlobal space, the one appears to be three-branched. Spines normal. Macroducts short, in barely discernible segmental series; four or five in the first duct furrow, seven or eight in the second, and about 12 in the third, with other series extending anteriorly sometimes to the first abdominal segment. Perivulvar pores absent. Anal opening large, two-and-a-half times its length from the bases of the lobes. Paravulvar folds long, slender and slightly curved. Pygidial margin with small indentations.

Notes.—The description given is from the type and type material in which all characters are not distinct. Most of the spines are abraded and the pygidial margins obscure the plates. In some specimens the apical margins of the lobes are convex, with or without a few small indentations, instead of being truncated and concave, and sometimes the two lobes differ. Paravulvar folds may be medianly divided. Most specimens do not show the macroducts as far anteriorly as the first abdominal segment. The separated lobes distinguish this species from *R. chenopodii*, while the macroduct orifices are fewer than those of *R. cassiniae*.

EULAINGIA new genus.

Generic type.—Pseudaonidia stenophyllae Laing.

Recognition characters.—Body subcircular to broadly pyriform with a thoracic constriction. Two pairs of lobes. Second pair of lobes close to the median pair and considerably smaller. Basal scleroses absent. Paraphyses in the first interlobal area single, apically clubbed. Anal opening close to the bases of the median lobes. Perivulvar pores absent. Reticulate chitinization medianly on the pygidium. Anterior spiracles with associated pores.

Notes.—The genus has affinities with *Pseudotargionia* and *Neomorgania*. It differs from *Pseudotargionia* in having distinctly clubbed paraphyses and from *Neomorgania* in having separated median lobes, and from both of these genera in having the second lobes almost contiguous with the median lobes.

Eulaingia stenophyllae (Laing) new combination.

(Figs. 19 and 20.)

Synonymy.

1929: *Pseudaonidia stenophyllae* Laing; Bulletin of Entomological Research, 20: p. 27.

Type locality and host.—Victoria: on the River Murray, near Hattah, on *Acacia stenophylla.*

Material examined.—Victoria: Lake Hattah, on *Acacia* sp., 1909 (J. E. Dixon); Warrandyte, on *Acacia melanoxylon,* 1922 (C. French). New South Wales: Euston, on *Acacia stenophylla,* Oct. 1928 (W.W.F.). Queensland: Bringalily Ck., on *Acacia harpophylla* F. Muell. ex Benth., Apr. 1910 (H. Tryon).

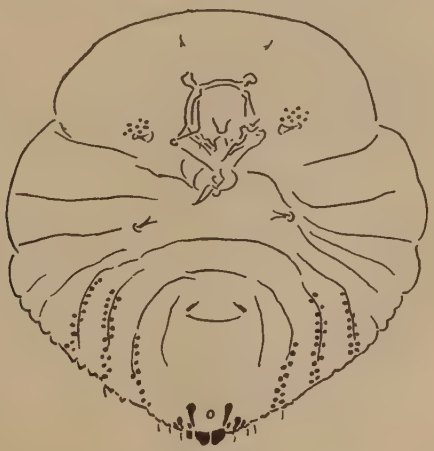

Fig. 19.

Eulaingia stenophyllae. Outline of Body. × 110.

Habit.—Insects single and sparse on twigs. Female scale circular, 1·2 mm. in diameter and light brown in colour; first pellicle darker.

Recognition characters.—Adult female subcircular to broadly pyriform, with a thoracic constriction; length of slide specimen 0·75 mm., width 0·6 mm.; anterior portion dome-shaped; posterior portion wider, semicircular. Pygidium broad, apex broadly obtuse, with two pairs of lobes. Median lobes large, as wide or wider than long; inner and outer margins almost parallel; apex broadly rounded with an inner indentation and a larger outer indentation; separated by one-sixth of one lobe's width. Second pair of lobes resembling the median but markedly smaller, width one-quarter that of a median lobe, as wide or wider than long, almost contiguous with the median lobes. Paraphyses as uneven pairs in the first and second interlobal areas; the inner in the first interlobal area elongate, longer than the lobes and ending in a round club; a similar but smaller paraphysis on the inner side of the second

interlobal area; those on the outer side of both the first and second interlobal areas little more than slight thickenings. Two plates in the second interlobal space, short and simple. The spines adjacent to the median lobes shorter than the lobes, other spines longer. Dorsal ducts short and slender; duct heads small; orifices in segmental series, few in the first and second furrows, 18 to 20 in the third furrow, more in the fourth and fifth and less in the sixth. Perivulvar pores absent. Anal opening small, close to the bases of the median lobes, in an inverted U, with an anal groove between the bases of the median lobes. Pygidial margin anterior to the lobes finely crenulate. Median pygidial area with a reticulate chitinization. Anterior spiracles with eight or nine associated pores.

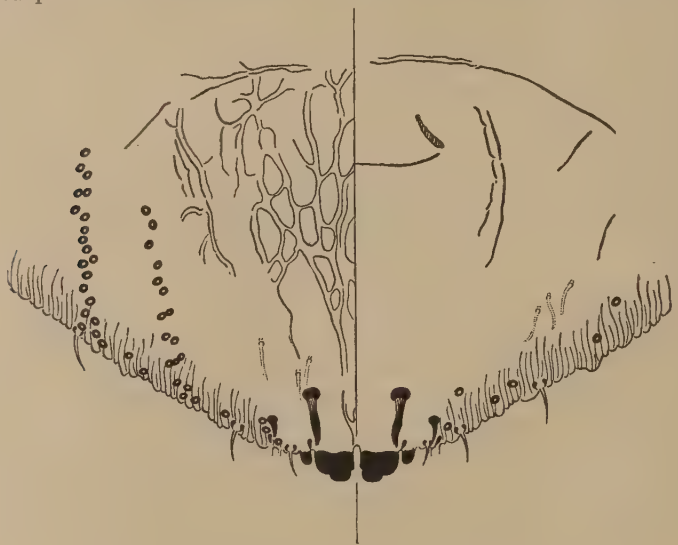

Fig. 20.

Eulaingia stenophyllae. Enlargement of Pygidium. × 265.

Notes.—In some specimens the body is membranous except for the chitinized reticulation on the pygidium; in old specimens the body may be uniformly densely chitinized in addition to the pygidial reticulation and the duct orifices then are obscure. The paraphyses in the second interlobal area may be obscure. Parastigmatic pores may be as few as four.

Genus **GREENIELLA** Cockerell.

Synonymy.

1899: *Greeniella* Cockerell; Bulletin of the Illinois State Laboratory of Natural History 5, p. 396.

1955: *Decoraspis* Ferris; Microentomology 20; p. 31.

Generic type.—Aonidia corniger Green.

Ferris apparently overlooked the fact that Cockerell and not MacGillivray (1921) established the genus *Greeniella.*

Greeniella truncata (Green and Laing) new combination.

(Figs. 21 to 23.)

Synonymy.

1923: *Aonidia truncata* Green and Laing; Bulletin of Entomological Research, 14: p. 129.

Type locality and host.—Queensland: Magnetic Island.

Material examined.—Specimens labelled "*Aonidia truncata,* Magnetic Is. N.Q., G. F. Hill, Paratype."

Habit.—Insects in small numbers on leaves. Female scale circular, 0·6 mm. diameter; second pellicle black, covering the adult body; first pellicle an orange colour with a grey margin; pale secreted filaments arising from the first pellicle.

Recognition characters.—Adult female membranous, globular, length of slide specimen 0·5 mm., width 0·4 mm. Pygidium broad, not differentiated, apex broad and truncated, with three pairs of inconspicuous lobes. Each pair of lobes of a similar though indefinite shape, more or less evenly spaced, the third pair marking the latero-apical angles of the truncated pygidial apex. Basal scleroses and paraphyses absent. Plates absent. Spines in normal positions, fine, longer than the lobes. Dorsal ducts slender, in the median area extending for two-thirds of the distance from the lobes to the vulva, orifices small and inconspicuous, one duct in the median area, three or four in the

Fig. 21.

Greeniella truncata. Outline of Body. × 135.

Fig. 22.

Greeniella truncata. Enlargement of Pygidium. × 325.

first duct furrow, two in the second furrow, others absent or not apparent. Anal opening round, anterior to the vulva. Vulva wide, half the distance of the anal opening from the lobes.

Second stage female, when young, membranous, subcircular, pygidium wide, indicated by light longitudinal chitinous striations, apex broadly rounded, with four pairs of lobes. Median lobes elongate, two to three times as long as wide, apex pointed, separated by a lobe's width. Second pair of lobes twice as

Fig. 23.

Greeniella truncata. Second Stage Female. Enlargement of Pygidium. × 375.

wide as long, broadly rounded to obliquely truncated, separated from the median lobes by almost the length of the latter. Third pair of lobes very wide, three times as wide as long, margin mostly with many minute indentations, separated from the second lobes by one-third to one-half of the latter's width. Fourth pair of lobes one-and-a-half or more times as long, margin minutely indented. Dorsal ducts few. Anal opening round, its own diameter distant from the bases of the median lobes, at the apex of a pair of large longitudinal chitinous pygidial folds, a second more lateral pair of folds longer than the median pair and reaching into the second interlobal area.

First stage nymph with a large area of reticulate chitinization between the ocelli.

Notes.—The fourth pair of lobes in the second stage female may be triangular points. Plates are present in the median first, second and third interlobal spaces. The anterior chitinization on the first stage nymph is unusual in the tribe Aspidiotini.

Monaonidiella bidens (Green).

(Figs. 24 and 25.)

Synonymy.

1915: *Aspidiotus bidens* Green; Bulletin of Entomological Research 6: p. 50.

Type locality and host.—Victoria; Lake Albacutya, on *Casuarina* sp.

Material examined.—Labelled "*Aspidiotus pauciglandulatus* Green n. sp., on Casuarina, Lake Albacutya, Victoria, 27-10-08, C. French."

Habit.—Insects scattered on twig. Scale circular, diameter 1.0 mm., white, pellicles dark orange.

Recognition characters.—Adult female subcircular, membranous, length of slide specimen 0·6 mm., width 0·5 mm. Pygidium large, not differentiated, with median lobes only. Lobes as wide as long, separated by one-sixth of a lobe's width; inner margins almost straight and subparallel or very slightly divergent; outer margins slightly curved with a large subapical indentation; apex rounded. Basal scleroses one-and-a-half times the length of the lobes. Paraphyses absent. Plates present in the first, second and third interlobal spaces; two in the first space, linear, simple, slightly shorter than the lobes; two in the second spaces, linear, simple, subequal in length to the lobes; one in the third space, conical, simple, shorter than the lobes. Spines adjacent to the lobes one-and-a-half times the length of the lobes, other spines longer. Dorsal ducts few, short, slender, length in the first furrow half the distance from the lobes to the anal opening; orifices normal, two in the first interlobal area, about six in each of the second and third duct furrows, others dispersed and segmental series indeterminate, a few ducts submarginally as well as marginally on the second, third and fourth abdominal segments. Anal opening oval, almost as large as a median lobe, five times a lobe's length from the bases of the lobes and about half the distance to the vulva. Paravulvar

Fig. 24.

Monaonidiella bidens. Outline of Body. × 130.

Fig. 25.

Monaonidiella bidens. Enlargement of Pygidium. × 255.

folds prominent, long, curved. Lateral and median scars and two pairs of additional dorsal scars present near the median line. Perivulvar pores and thoracic tubercle present.

Notes.—Basal scleroses may be as much as twice as long as the lobes, and slightly divergently curved. Sometimes there is an indication of a small subapical indentation on the inner margin of the lobes. The plates may have blunt apices, and the one in the third interlobal space may be abraded and not distinct. The anterior lateral perivulvar pore groups may contain one to three pores and a single lateral posterior pore is sometimes present. The thoracic tubercle may not always be evident. Green recorded only three plates on each side of the pygidium and apparently did not detect the perivulvar pores, which are clear only in good mounts.

"*Aspidiotus pauciglandulatus* Green" is a label name only. The determination of the present material has been confirmed by comparison with the type in the British Museum.

This species differs from *M. cerata* (Maskell) in having only one plate in the third interlobal space; the spines are longer; the dorsal ducts on the second, third and fourth abdominal segments are sparse, and the ducts in the first furrow do not extend to the anal opening.

EUGREENIELLA new genus.

Generic type.—Aonidia (*Greeniella*) *pulchra* Green.

Recognition characters.—Body of adult female completely covered by the second pellicle, membranous; pygidial apex broadly truncated with an irregular number of short rounded processes; lobes and plates absent; ducts sparse, small and short; perivulvar pores absent.

Second stage female with three pairs of uniformly shaped elongate lobes with apparent lobes in the fourth and fifth lobe positions; plates numerous extending anteriorly to the fifth lobe position; macroducts large, in the first, second, third and fourth pygidial interlobal areas.

Notes.—The genus resembles *Greeniella* in having filaments from the first pellicle and the adult female completely covered by the second pellicle. The indefinite pygidial apex is also a character shown by *Greeniella*. The absence of lobes in *Eugreeniella* is, however, an outstanding difference.

The second stage female shows greater differences. The first three pairs of lobes are of similar shape, whereas in *Greeniella* those of the third pair are extremely wide. The ducts are short and broad with large heads and wide orifices while in *Greeniella* they are long and slender with small heads and orifices.

There is also a resemblance to *Aonidia*, which has the first three pairs of lobes in the second stage female of somewhat uniform shape and size, but in *Aonidia* the adult has definite lobes and a large lobe in the position of the fourth lobe in the second stage female.

The above comparisons are of value if the generic type belongs to the tribe Aspidiotini. The diagnosis of Green (1905) places the species in this tribe but he indicated that the second stage female has a pygidial margin resembling that of *Parlatoria* and later stated that the second pellicle presents characters found in the genus *Gymnaspis*. These resemblances have been confirmed but are relevant only if *Eugreeniella* belongs to the tribe Diaspidini. A detailed study of duct heads in adult and second stage females and nymphs has shown in most instances a two-barred head with the first bar appearing as the cap of the duct head. Heavy staining in this first position has been taken to represent a bar. The membranous duct head cap in addition to the two bars is distinct in the second stage males and the genus therefore is now regarded as belonging to the tribe Diaspidini.

Differences in *Eugreeniella* from *Gymnaspis* as illustrated by Ferris (1936) are the third and fourth lobes of the second stage female are not bilobed, the ducts are fewer in number, and the duct orifices have uniform rims. The posterior pygidial margin and derm processes of the adult are different from those of *Gymnaspis*. The outstanding difference from *Parlatoria* is the absence of perivulvar pores, lobes and plates.

Eugreeniella pulchra (Green) new combination.

(Figs. 26 to 28.)

Synonymy.

1905: *Aonidia* (*Greeniella*) *pulchra* Green; Victorian Naturalist 22; p. 4.

1921: *Aonidia pulchra* Green; MacGillivray; The Coccidae, p. 464.

Type locality and host.—Victoria: Myrniong, on *Callistemon salignus*.

Material examined.—Specimens labelled "*Aonidia pulchra*, *Callistemon lanceolata*, Werribee River, Victoria, 20.10.16, C. French," and specimens collected on *Callistemon* sp., Botanic Gardens, Melbourne, Dec. 1955.

Habit.—Insects sparse to numerous on the leaves of the host. Female scale consists of the large, heavily chitinized second pellicle, circular, 0·7 mm. diameter, strongly convex, brown but covered with a pale grey suffusion, completely covering the adult female. First pellicle comparatively large, central, orange coloured.

Male scale oval, brownish black with a pale fawn margin; first pellicle eccentric and orange coloured.

First pellicle of both sexes with a series of lateral and dorsal pale secreted filaments, often partly abraded from mature specimens.

Recognition characters.—Adult female membranous, subcircular, length of slide specimen 0·6 mm., width 0·6 mm. Pygidium broad, not differentiated, posterior part broadly truncated with an irregular number of irregularly placed, short, apically rounded derm processes. Lobes and plates absent. Spines short and fine. Ducts submarginal, small, short, heads narrow, orifices indistinct.

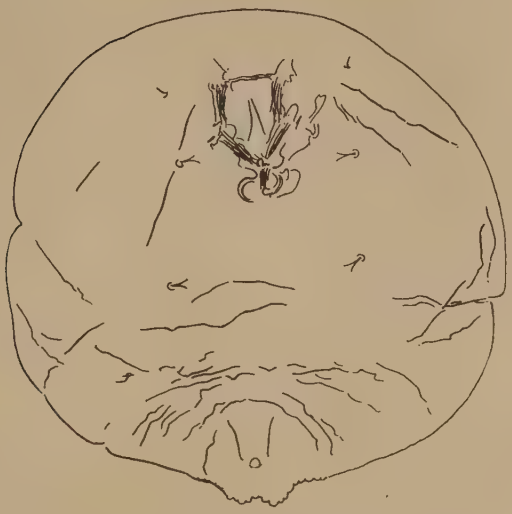

Fig. 26.

Eugreeniella pulchra. Outline of Body. × 120.

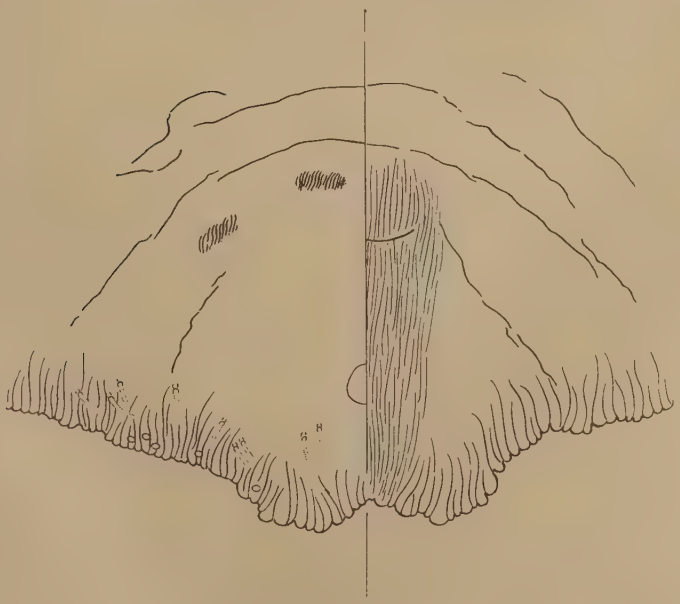

Fig. 27.

Eugreeniella pulchra. Enlargement of Pygidium. × 390.

Perivulvar pores absent. Median and lateral scars rather faint. Anal opening circular, three times its diameter from the end of the pygidium. A median band of light chitinization on the pygidium narrowing posteriorly.

Second stage female fully developed as represented by the second pellicle, heavily chitinized, mostly circular, diameter 0·7 mm. Young second stage female much smaller, membranous, subcircular; pygidium not demarcated but with longitudinal slightly chitinous striations. Three pairs of uniformly shaped lobes (see notes). Median lobes elongate, twice to three times longer than wide, separated by a lobe's width; inner margins with a lateral indentation; outer margins with a preapical indentation; apex rounded. Second pair of lobes similar in general shape and size to the median lobes, but slightly wider basally, longer than wide, separated from the median pair by one-and-a-half times a

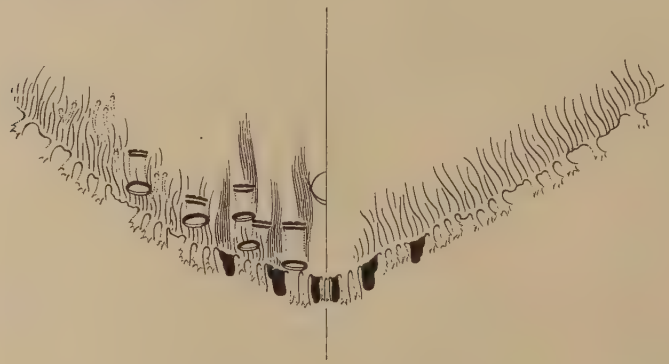

Fig. 28.

Eugreeniella pulchra. Second Stage Female. Enlargement of Pygidium. × 340.

second lobe's width; third pair of lobes similar in general shape and size to the second pair of lobes except that there are two indentations on the outer margin, separated from the second pair by two to three times the latter's width. Two plates in the median interlobal space, elongate slender, as long as the lobes, apically shortly bifid; two plates in the first interlobal space wider than those in the median space, as long as or slightly longer than the lobes, apically bifid, lateral margins with incipient branches; three plates in the second interlobal space, as long as the lobes, the posterior one slender, apically pointed, with lateral serrations, the other two plates wider, similar to each other, variously branched; three plates in the third interlobal space similar respectively to those in the second space; three plates in the fourth interlobal space slightly different from but of the same general appearance as those in the third space; three to five other plates anteriorly, becoming smaller, mostly pointed but with lateral branches. Spines small and fine, shorter than the lobes. Macroducts on mature chitinized second stage females five only, short, wide, with wide heads and orifices, one orifice marginal in the first, second, third and fourth interlobal

areas with a submarginal orifice in the second interlobal area. Anal opening small, round, two-and-a-half to three times a median lobe's length from the bases of these lobes.

Notes.—The irregularly shaped pygidial apex, the absence of lobes and plates, and inconspicuous ducts in the adult female of this species limit the diagnostic characters. These morphological features are well developed in the second stage female and this stage therefore is of value in the determination of the species.

In some second stage females the median lobes may have the inner margin slightly concave and the lobes appear slightly crescentic. The second pair of lobes may have two indentations on the outer margin. Some specimens have a lobe-like projection in the position of the fourth lobe and a similar but smaller projection in the position of the fifth lobe. These lobe-like structures do not stain as do the other three pairs of lobes and therefore are not so well chitinized. In shape they are elongate, slightly shorter than adjacent plates, sometimes with indentations on the outer margin. These structures are definite lobes in the second stage males. In young unchitinized second stage females there is a series of small submarginal dorsal ducts extending anteriorly from the macroducts. In the males the ducts are progressively smaller from the first interlobal area.

ALIOIDES new genus.

Generic type.—Aspidiotus tuberculatus Laing.

Characters.—Adult female membranous, broadly pyriform, thoracic and prepygidial segments with large membranous derm flanges. Pygidium with median pair of lobes only. Basal scleroses, normal plates and perivulvar pores absent. Paraphyses unpaired in the first and second interlobal areas. Gland spines on pygidium, that in the first and second interlobal space large and lobe-like. Macroducts short, wide, heads wide, two-barred, orifices oblique and on the gland spines.

Notes.—The pygidial gland spines resemble lobes in appearance and density of staining. Laing (1929) mistook these for lobes, but his placing of the species in *Aspidiotus* was provisional only.

In the Diaspidini the genus *Alioides* is unique in having large membranous flanges laterally on the thoracic and prepygidial segments. The few large macroducts with large orifices on gland spines, which in the first and second interlobal spaces are lobe-like, are also outstanding characters.

Alioides tuberculata (Laing) new combination.

(Figs. 29 and 30.)

Synonymy.

1929: *Aspidiotus tuberculatus* Laing; Bulletin of Entomological Research 20: p. 24.

Type locality and host.—Northern Territory: Darwin, on *Melaleuca* (G. F. Hill).

Material examined.—Specimens labelled "*Aspidiotus tuberculatus* Laing *Mel. leucadendra*, Darwin, N.T., 26.6.17, G. F. Hill, Paratype, Part of Type Material, No. 685."

Habit.—Insects numerous on foliage. Female scales oval, dark brown to black, length 0·6 mm.; pellicles eccentric, dark orange to brown.

Recognition characters.—Adult female membranous, broadly pyriform, length of slide specimen 0·5 mm., width 0·4 mm., lateral margins of thoracic and prepygidial segments with large membranous derm flanges. Pygidium broadly rounded, with median pair of lobes only. Lobes almost contiguous, wider than long, slightly constricted basally on both margins, margins simple, apex broadly rounded. Basal scleroses absent. Paraphyses in the first and

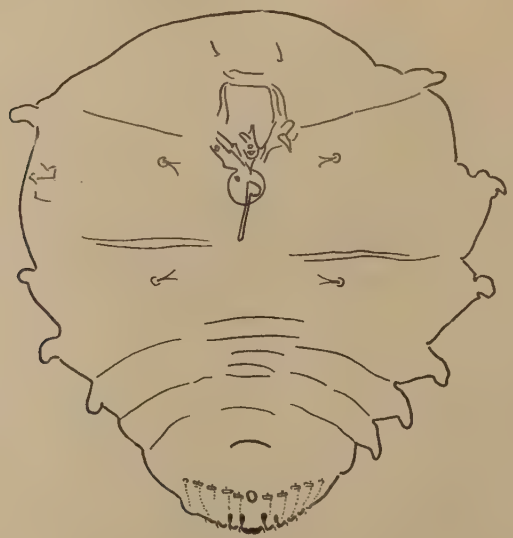

Fig. 29.

Alioides tuberculata. Outline of Body. × 140.

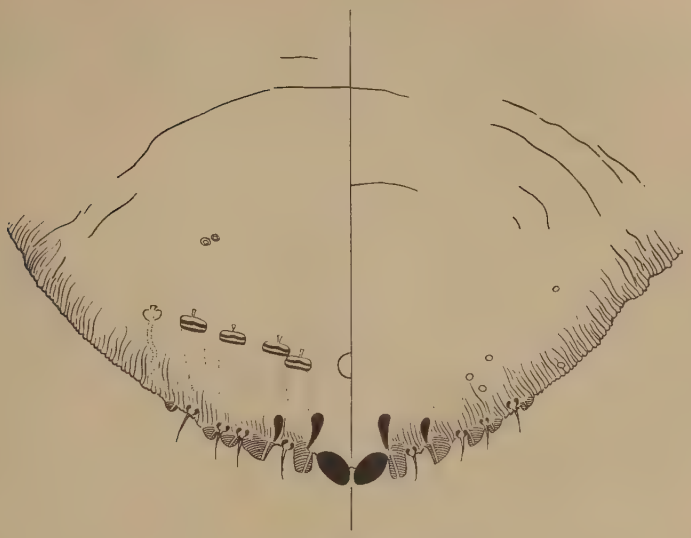

Fig. 30.
Alioides tuberculata. Enlargement of Pygidium. × 370.

second interlobal areas not paired; the first longer than the lobes, the second subequal in length with the lobes. Normal plates absent, but large gland spines present. Gland spine in the first interlobal space quadrate, slightly longer than wide, as long as the lobes, the oblique duct orifice making the apex appear divided; gland spine in the second interlobal space slightly wider than long, triangular; two gland spines in the third interlobal space, posterior one broadly rounded, the other much smaller; one other smaller rounded gland spine on the pygidial margin. Spines other than near the lobes longer than the lobes. Five macroducts only, short, slightly exceeding the distance from the lobes to the anal opening, wide, heads wide, orifices wide, opening obliquely on the gland spines. Perivulvar pores absent, anal opening small, round, four times the length of the lobes distant from the lobes. Vulva three times distance of anal opening from the lobes.

Notes.—The gland spines are large and lobe-like, and were mistaken for lobes by Laing (1929). Basal constrictions of the inner margin of the lobes give these an oval and apically convergent appearance.

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CORRECTIONS.

"Studies of the Coccoidea. 2. Revision of Some of the Australian Aspidiotini Described by Maskell."

The following corrections should be made to the article with this title which appeared in Vol. 11 of this Journal.

p. 152, line 14. "first" should read "second"; "second" should read "third".

p. 152, line 15. "third" should read "fourth".

STUDIES OF THE RESISTANCE OF SPECIES OF *PASSIFLORA* TO FUSARIUM WILT *(F. OXYSPORUM* F. *PASSIFLORAE).*

By G. S. PURSS, B.Sc. Agr., Pathologist, Division of Plant Industry.

SUMMARY.

It is possible to obtain a degree of resistance to Fusarium wilt in the purple passion fruit (Passiflora edulis) **but the resistance so far located has only been sufficient to delay infection. This would be of little value commercially, where a high level of resistance is required to suit a perennial plant.**

Some other species and varieties of Passiflora **possess good resistance to the disease and certain strains of the golden passion fruit** (P. edulis f. flavicarpa) **possess characters suited to their use as resistant rootstocks.**

I. INTRODUCTION.

A wilt disease of the purple passion vine (*Passiflora edulis* Sims) is of major importance in Queensland. This disease has been described as Fusarium wilt (McKnight 1951) and the causal agent identified as *Fusarium oxysporum* Schlecht. em Snyder and Hansen f. *passiflorae* (Purss 1954). The disease has since been reported in New South Wales on *P. edulis* at Kulnura, Taree (New South Wales Department of Agriculture 1953).

The passion fruit is by nature a perennial which is expensive to establish on account of the trellising required. The effect of a disease of this nature which completely destroys affected plants and renders the field useless for replanting is disastrous. The disease was at first localised but with gradual spread it has now become so prevalent in south-eastern Queensland that it has to be considered one of the normal hazards to successful cultivation.

McKnight (1951), following resistance tests, suggested that control might be achieved either by selecting resistant individuals within *P. edulis* or by top-grafting *P. edulis* onto the root system of a suitable resistant species of *Passiflora*. Since then the reaction of many individuals of *P. edulis* and other species of *Passiflora* has been investigated with a view to determining their value as rootstocks. This paper records the results of these studies.

II. TECHNIQUES OF TESTING FOR RESISTANCE.

Three techniques of inoculating seedlings with *F. oxysporum* f. *passiflorae* were compared.

(1) *Fungus-slurry method.*—This technique was used by McKnight (1951). Inoculum is prepared by scraping the spores and mycelium from the

Fig. 1.

Passiflora edulis Vine on a *P. edulis* f. *flavicarpa* Rootstock.

surface of a potato dextrose agar (P.D.A.) culture of the test fungus and adding this to a small quantity of water. The seedlings, with 1-3 true leaves, are removed from the soil and their roots thoroughly washed in running water, then dipped into the inoculum. They are then replanted. Check plants are dipped in water free from inoculum. This technique is a laborious one when testing large numbers of seedlings.

(2) *Nutrient solution method.*—The nutrient solution described by Sherbakoff, Miller and Simpson (1944) was inoculated with small pieces of a P.D.A. culture of the fungus and left for two days with occasional agitation. This solution was then used for inoculating flats of moist sterilized soil at the rate of 500 ml. to approximately every square foot of soil. Into this soil either seedlings or seed of the species being tested were placed.

Typical results of both these methods of testing appear in Table 1.

Table 1.

RESULTS OF DIFFERENT INOCULATION TECHNIQUES WITH *F. oxysporum* f. *passiflorae* ON *P. edulis.*

Treatment.	Number of Plants.	Percentage Mortality After 1 Month.
Soil inoculated with nutrient solution. Seedlings planted immediately	14	65
Soil inoculated with nutrient solution. Seed sown immediately	66	71
Seedlings dipped in fungus-slurry, then planted immediately	17	100
Check. Seedlings dipped in water and replanted	17	0

(3) The third method of testing was simply to re-use the soil from flats in which seedlings inoculated by the fungus-slurry technique had died. Results here were very inconsistent, some seedlings taking a considerable time to show symptoms of the disease.

Because of its overall effectiveness the fungus-slurry technique was adopted. A possible objection to this method of testing is that it is too severe and not comparable with normal disease conditions in the field. However, as passion fruit is a perennial crop, subject to attack at all stages of maturity, resistance must be on an extremely high level to be worthwhile.

III. REACTION OF PASSIFLORA EDULIS.

Tests were carried out over a period of three years on seed collected from 10 different localities. Seedlings were inoculated in the 3-leaf stage with one isolate of *F. oxysporum* f. *passiflorae*. All survivors were inoculated with a mixture of a number of isolates obtained from different sources.

A total of 2,258 seedlings was treated in this way. Forty-eight seedlings survived the first inoculation but only six of these survived the second. These six surviving plants were planted out in the open, where five of them quickly wilted and died. All were found to be affected with Fusarium wilt.

The sixth plant survived for six months but eventually wilted and died from the same cause. Cuttings struck from this plant succumbed to the disease when planted out in infected soil. Scions of this "resistant" plant grafted on a resistant rootstock reached maturity and set seed. The reaction of its progeny was compared with that of an ordinary *P. edulis* line. The results appear in Table 2.

The resistance so far located in *P. edulis* is therefore of a very low order, tending only to delay symptoms of the disease. Such resistance would be of no value commercially.

Table 2.

COMPARISON OF RESISTANCE TO FUSARIUM WILT OF PROGENY OF A "RESISTANT" PLANT AND NORMAL PLANTS OF *P. edulis*.

Seed Source.	Number of Plants.	Percentage Infection After 90 Days.
"Resistant" Plant	48	69
Normal Plant	25	100

IV. REACTION IN OTHER SPECIES OF PASSIFLORA.

McKnight (1951) has already given figures indicating the reaction of certain species of *Passiflora* to Fusarium wilt. The reaction of additional species together with more figures of those previously tested are recorded in Table 3. Where more than one seed line of any species has been tested the results of each line are shown separately.

Table 3.

RESULTS OF INOCULATING SPECIES OF *Passiflora* WITH *F. oxysporum* f. *passiflorae*.

Species.	Number of Plants Inoculated.	Percentage Infection.
P. aurantia Forst	14	0
P. caerulea L.	22	16
P. edulis Sims f. *flavicarpa* Degener. (Local strains) 1	50	58
P. edulis Sims f. *flavicarpa* Degener. (Local strains) 2	27	48
P. edulis f. *flavicarpa* (Introduced strains) .. 1	75	8
P. edulis f. *flavicarpa* (Introduced strains) .. 2	69	13
P. edulis f. *flavicarpa* (Introduced strains) .. 3	65	1·5
P. edulis f. *flavicarpa* (Introduced strains) .. 4	79	33
P. edulis X *P. edulis* f. *flavicarpa* (F_3 seed from Ayr) ..	59	53
P. foetida L.	13	100
P. herbertiana Lindl	14	0
P. incarnata L.	15	0
P. maliformis L. 1	50	98
P. maliformis L. 2	47	92
P. suberosa L. 1	50	24
P. suberosa L. 2	96	24
P. suberosa L. 3	73	93
P. suberosa L. 4	10	20
P. subpeltata Ortega	100	100
Tacsonia sp. (banana passion fruit) 1	31	100
Tacsonia sp. (banana passion fruit) 2	10	100

V. RESISTANT ROOTSTOCKS AS A MEANS OF CONTROL.

In the absence of evidence of resistance in *P. edulis* other species of *Passiflora* assume importance as possible rootstocks for grafted plants. Of those species exhibiting good resistance, *P. aurantia*, *P. herbertiana* and *P. suberosa* are narrow-stemmed types unsuitable for grafting.

P. caerulea has been developed as a passion fruit rootstock by Victorian nurserymen. It appears to be resistant to Fusarium wilt under field conditions. However, it has several serious disabilities which make it unsatisfactory in Queensland.

The potentialities of *P. incarnata* as a stock are not known, as the species became available only recently.

Of all the species tested, introduced lines of *P. edulis* f. *flavicarpa* were the most promising. They possess very vigorous root systems and do not sucker. They have a stem base approximately the same diameter as that of *P. edulis* and their compatability with the latter is good (Groszmann and Purss 1958).

The commercial development of this method of overcoming the Fusarium wilt problem will depend largely upon whether it is economical to use grafted plants. The output of passion vines on *P. caerulea* stock by southern nurserymen suggests that there should be no great difficulty involved.

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